THE INFLUENCE OF CHEMISTRY

ON THE

Development of a Rational System

OF

STOCK-FEEDING.

BY

PROF. CHARLES A. GOESSMANN,

MASSACHUSETTS AGRICULTURAL COLLEGE.

EXTRACT FROM THE THIRTIETH ANNUAL REPORT OF THE SECRETARY OF THE BOARD OF AGRICULTURE.

BOSTON:
WRIGHT & POTTER PRINTING CO., STATE PRINTERS,
18 POST OFFICE SQUARE.
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THE INFLUENCE OF CHEMISTRY ON THE DEVELOPMENT OF A RATIONAL SYSTEM OF STOCK-FEEDING.

The importance of a knowledge of chemistry for a satisfactory explanation of various physiological and pathological questions arising in the study of animal life has been for ages recognized.

The attempt of Paracelsus (1540), and a succeeding school of physicians, to explain most intricate physiological processes in the animal organism by the aid of the limited chemical experience of their time, as well as by the assumption of an ill-supported analogy of chemical and physiological reactions, caused only a temporary decline in the appreciation of chemistry on the part of physiologists and physicians. The adoption of more exact modes of chemical observation towards the close of the last century, not only restored the former confidence in its teachings, but secured to chemistry, in common with physics, a controlling influence on the development of the more rational animal and vegetable physiology of the present day.

The introduction of the balance, by Lavoisier in 1783, into the laboratory of the chemist, for the purpose of studying the chemical changes of all substances under their treatment *henceforth by weight*, inaugurated the new era. A careful use of this instrument soon demonstrated two important facts: —

First: Matter cannot be destroyed.

Second: All chemical combinations are characterized by definite proportions of their constituents.

It became evident that, however thoroughly the various qualities of a substance may be altered, one quality could not be destroyed, neither by physical nor by chemical agencies — namely, its weight; and also that under whatever varying circumstances a certain definite chemical compound might have been produced, the same relative quantity of its elementary constituents is in every case required for its production. To account for the entire original quantity of the constituent elements of a substance throughout all its various stages of transformation, became an indispensable attribute of an acceptable explanation of an experimental observation in chemistry. The chemist of the new era, in the language of the founder of modern chemical, animal physiology, aimed at a more concise description of the observation and proposed to control the latter by number and weight.

The speedy general recognition of the above stated facts exerted soon a thus far unknown influence on many current opinions regarding the true character of well-known changes of all kinds of substances; it controlled the proper selection of suitable subjects for future inquiry, and caused a more judicious choice of means to obtain the needed information.

Among the first important results of the application of careful quantitative modes of examination are found the determination of the composition of water, the analysis of the air, and a correct experimental demonstration of the function of the air in the process of ordinary combustion, as well as of animal respiration, information of the first importance regarding the topic under discussion.

For nearly thirty years, until 1820, inorganic substances almost exclusively engaged the attention of chemists.

The gradual perfection of analytical modes for the examination of inorganic substances had led to the discovery of many new elements. The study of their chemical and physical properties, as well as of their relations to previously known elementary substances; the analyses of minerals, of soils, of the ashes of plants, and of industrial products in general, had furnished abundant subjects for investigation during that period. Organic substances, on account of inefficient modes of analysis, had received but little attention; comparatively but a few chemists had devoted themselves thus far to the study of organic compounds. Most noteworthy among them were Thenard and Gay-Lussac, two distinguished French chemists, who followed the course pointed out by Lavoisier. The unsatisfactory condition of organic chemistry was to be changed materially by the genius and the indomitable will of one man, who at this stage of the history of chemistry entered the field of chemical research — Justus von Liebig. As the scientific labors of this remarkable man are closely identified with the development of the science of animal nutrition, I may be pardoned for treating somewhat more in detail of the circumstances which led him to exert a controlling influence on our present views regarding the science of stock-feeding. Having pursued the study of chemistry for four years at German universities, he had the good fortune to work for two years in the laboratory of Gay-Lussac at Paris, the most skilful experimenter in organic chemistry of the time.

Naturally inclined to the study of organic substances, he felt soon seriously the great need of better modes of elementary organic analysis. His first efforts were therefore directed towards that end as soon as he returned to his native country, Germany, as professor of chemistry in the university of Giesen in 1824. The results obtained in that direction by him, and those who benefited by his instructions, after five years of careful work, are a lasting monument of skill and perseverance ; they have made his name familiar to every chemist, and have earned for him the name of founder of organic chemistry. The rapidity of the execution of an organic elementary anaylsis and the unsurpassed exactness of the analytical results obtained, tended to increase in an unusual degree the knowledge of the true elementary composition of many organic substances and placed the analytical modes of organic chemistry even above those of inorganic chemistry of the time. Enthusiastic students of chemistry from all parts of the world soon flocked to his laboratory, which, endowed by the munificence of the government of the duchy of Hessen-Darmstadt, opened its doors on equally liberal terms to all, without regard to nationality.

Supported in many of his intricate and most important investigations of organic substances by his life-long friend, F.

Wöhler, one of the most thorough and most successful investigators during the past fifty years, and surrounded by numerous and interested pupils, who frequently soon developed into valuable assistants and successful co-laborers, he secured within a period of fifteen years, from 1824 to 1839, a rich store of experimental observations regarding the elementary composition, as well as other important qualities of a large number of organic substances of every description. His superior knowledge of the characteristics of organic compounds induced him to venture upon the study of the essential proximate constituents of plants and of animals, their food, their secretions and their excretions; it may suffice here to refer in this connection to his examination of the nitrogenous substances of plants and of animals, of the blood, of the flesh, of the composition of the bile and of the urinary secretions. Liebig's main efforts since 1840 were directed towards the application of chemistry in agriculture and in physiology.

The name, organic substance, had thus far been reserved for the products of vegetable and animal life. Wöhler's successful artificial production of a prominent constituent of animal secretion — urea — in 1828, was still the only noted instance of a decidedly organic substance having been produced without the assistance of the animal organism. Only a limited number of scientists looked upon that discovery as the first practical demonstration of chemical possibilities regarding the study of vital activity. The production of organic substances in the organism of plants and of animals was ascribed to a peculiar agency called vital force, and it was not less almost universally accepted, that their chemical relations to each other as well as towards inorganic matter in general were widely differing from observations obtained in the study of inorganic matter.

Liebig dissented at an early date almost instinctively from that view. To him there was but one science of chemistry, equally applicable to organic and inorganic substances. Although recognizing at any period of his life the peculiar influence of the living organisms on the production of organic compounds, he did not hesitate to assume that the vital energy in its construction of organic substances would follow the general laws which govern chemical transformations.

The first systematic and concise statement of his advanced views was published at the special request of the British Association for the Advancement of Science at their Liverpool meeting in 1837, namely: "To report on the condition of organic chemistry." His reply to this flattering invitation is contained in a publication which appeared in 1840: "Chemistry in its application to Agriculture and to Physiology." This masterly presentation of the experimental observations of preceding times as well as of his own extensive investigations regarding organic compounds, not less than the bold enunciations of his personal views concerning their bearing on vital points in the life of plants and of animals, created an unusual sensation among scientists and intelligent agriculturists everywhere. The great influence of this publication, and its six revised editions, on the development of a rational agricultural practice, as well as on the science of physiology, is a recognized fact.

Liebig's services to animal physiology are prominent in two directions, namely: *First*, on account of his extensive analytical examinations of numerous organic substances, of the proximate constituents of plants which serve as food for animals, and of the chemical changes they undergo during their passage through the animal system; and, *second*, on account of the direction he has given to the modes of observation to be applied in the study of animal physiology, by substituting the empirical experimental methods for the speculative philosophical one of preceding periods. A cursory study of the views of leading physiologists before 1840 cannot fail to concede to him a controlling influence on our present views regarding the principles which underlie a rational system of animal nutrition. Liebig's classification of the constituents of the animal food into three distinct groups, namely, *Nitrogenous substances*, *non-nitrogenous substances, and mineral substances*, furnishes the frame-work of the more rational system of stock-feeding of to-day.

Although it had been noticed for years that some articles of animal food contained the element nitrogen as one of their constituents, whilst others contained none — nitrogenous and non-nitrogenous substances — experience has furnished ample proof during famine, in war, and under other exceptional circumstances, that one single article of food, in particular those which contained no nitrogen, could not sustain life beyond a limited period of time; yet no satisfactory explanation of the real cause of death in those cases had been advanced. The force of this statement may be deduced from a subsequent brief enumeration of some feeding experiments carried on by distinguished scientists between 1830 and 1840. Several of the following experiments were made in connection with a prize question offered for general competition by the "French National Academy," one of the foremost scientific associations of Europe:

"Is the animal gelatine obtained by the boiling of bones, a suitable animal food?"

1. *Experiments with non-nitrogenous Substances.*

(Sugar, starch, gum, butter, etc.)

Magendie fed a dog with sugar. The dog died on the thirtieth day, in spite of large consumption during the first period of the trial. Five-sixths of the muscles had disappeared, and even the fat was gone. Similar results were obtained when feeding butter; the latter passed finally undigested through the animal.

Tiedemann and Gmelin fed geese with dextrine and with starch. In the first instance the animal had died on the sixteenth day; its weight had been reduced from five and two-thirds to four and two-thirds pounds. In the second instance the animal had lived twenty-seven days, and its weight had been reduced from eight and a half to six and a quarter pounds.

2. *Experiments with nitrogen-containing organic Substances.*

(White of the egg, flesh freed from fat, animal gelatine, etc.)

Magendie fed a lot of dogs with the white part of eggs. After a few days of the trial, they preferred to die by starvation rather than to consume for any length of time the rich nitrogenous food. A second lot of dogs were fed with animal muscles freed from fat. They consumed, at the beginning of the trial, every one of them, from one to two pounds of that rich nitrogenous substance per day. All died between from fifty to seventy-five days. A third lot were fed with the animal gelatine obtained from the boiling of bones, which they consumed at first freely. They all had died before the twentieth day had passed by. The animals which served in these experiments had in every case lost their muscles and their fat. The result of these trials had left no doubt about the fact, that a single proximate organic constituent of plants or of animals, whether nitrogen-containing or not, could not be considered in itself an efficient animal food. The reason why it should be thus, or on what basis the various proximate constituents of plants and of animals should be compounded for a healthy animal diet, was evidently not yet understood.

Physiologists and anatomists had studied during preceding periods, the various manifestations of motion in the animal organism; the forms and constructions of the principal organs, the history of their development and of their growth; the process of absorption and of secretion, etc., with a skill and a perseverance which deservedly called forth the admiration of the time; yet the character of many of the chemical processes which transpire in the living animal organism was but little understood, and their intrinsic relations to definite physiological processes, for obvious reasons, scarcely suspected.

The classifications of the various articles of animal food with reference to their relative feeding value, on the part of leading physiologists of that time, furnish one of the most striking illustrations of the change which has taken place in that direction. A classification of articles of food with reference to quantity and quality of their essential proximate constituents did not exist; the idea that some of these constituents might have to perform different functions in the animal economy than others did not yet enter into their consideration.

A cursory discussion of the circumstances which led to the recognition of the special functions of the principal constituents of plants in animal nutrition may serve as farther proof of the great influence which chemistry has exerted on our present notions of the relative nutritive value of our various articles of fodder for farm animals.

1. *Nitrogenous Constituents of Food.*

(Protein substances.)

Representative Forms.
Albumen — Eggs, blood serum, plants.
Casein — Milk; leguminous plants, beans, etc.; legumen.
Fibrin (solid) — Blood changes into it; gluten in wheat, etc.
(They occur in the vegetable and animal kingdom.)

The beginning of a better knowledge of the special relations of nitrogen-containing organic constituents of the animal food to animal nutrition may be traced directly to examinations of that class of substances by Mulder, Liebig and his pupils from 1830 to 1840. Their extensive investigations of many of our farm plants proved, contrary to current opinions, that all plants, and all parts of these plants, contain nitrogenous constituents of various descriptions, and as a rule in much larger proportions than generally conceded. Seeds and young plants showed more than natural stems and leaves.

Liebig was the first scientist who pointed out the close chemical relations which exist between the three principal forms of nitrogenous constituents of plants and of animals; namely, albumen, fibrin and casein.

He recognized, by careful analyses, an exceptionally large accumulation of these substances in the seeds of many of our prominent farm crops; and found also that the blood, the milk, the flesh, the muscles and the texture of animals showed similar remarkable features in their composition. He finally demonstrated, by actual experiment and otherwise, that the vegetable organism, or the plant, alone was capable of producing from more elementary compounds, like carbonic acid, water, ammonia and some mineral constituents, the complex nitrogen-containing proximate constituents of plants and of animals. As he had proved, also, that the animal was incapable of producing in its own organism the most characteristic constituents — as far as quantity and quality were concerned — of its own blood and flesh, etc., it became evident that the healthful and normal condition of the animal, depended in a controlling degree, on the amount of certain nitrogenous substances contained in the vegetable food consumed. The desirability of compounding the diet of the animal, as far as the supply of nitrogenous constituents is concerned, with special reference to the particular wants of its organization, as well as its conditions and its functions, became not less apparent. I need scarcely to point out that in the light of Liebig's teachings, the time-honored practice of using the seeds of our cereals, some prominent leguminous plants (clover, beans, pease, etc.), the brans and the oil-cakes for enriching the fodder of farm stock finds for the first time in the history of agriculture an intelligent explanation. Liebig called the nitrogenous constituents of the animal food, on account of their close relation to the formation of blood and flesh, the plastic constituents of the food, and considered them the source of animal energy, or interior and exterior phenomena of motion.

II. *Non-Nitrogenous Constituents of Food.*

(As starch, sugars, organic acids, cellular substance, dextrine, gums, fats, etc.)

The composition and the general character of some of the principal non-nitrogenous organic plant constituents, and their relation to the animal economy, engaged Liebig's attention not less than that of the nitrogenous substances.

Many organic substances, which did not contain nitrogen, had already been studied with more or less success by other chemists, before Liebig turned his scientific efforts towards the application of chemistry in the study of animal physiology.

The elementary composition of the starch, the sugars, the fats, the principal organic acids, cellular substances, etc., was known; all consisted of but three elements — carbon, hydrogen, oxygen.

The fats of plants and of animals had been carefully studied by Cheuvoreal and others; it had been proved that they are composed of the same constituents, and that they are in every way identical. The changes of the starch and the vegetable cellular mass into sugar by the aid of mineral acids, and of the sugar into carbonic acid and alcohol by means of some nitrogenous organic matter, had been described.

Liebig's main efforts in this connection were directed towards the study of the origin and the functions of the fat in the animal system.

But little attention had been thus far paid to the solution of these questions.

The animal fat was still considered a kind of stored up food, which in time of need would support life in consequence of an assumed disposition to combine with the nitrogen of the air, forming thereby nitrogen-containing animal matter, like blood and flesh. Liebig, for obvious reasons, discarded these opinions. His own experience induced him to teach, as far as the origin of the fat in the animal system was concerned, that quite frequently a large proportion of the animal fat was produced in the animal, and not merely derived from the vegetable food it had consumed. He did not deny that the fat contained in the latter was absorbed during the process of digestion, without any material change in its general character; he simply ascribed to the animal organism the power to convert, not only substances like starch and sugar, but also nitrogenous compounds, into neutral animal fats.

Practical observations as well as scientific considerations furnished the arguments for his views. The large accumulation of fat noticed in well-fed cattle, sheep, pigs, and fowls could hardly be ascribed to the amount of fat found in the food consumed. Men living largely on a diet rich in starch and in sugar, as a rule, are more apt to accumulate fat than those living mainly on meat. On the other hand, the peculiar action of the saliva on starch, changing it into sugar, and of certain nitrogenous substances on the latter, changing the sugar into acids found in natural fats, besides the well-known degeneration of muscles and flesh parts of the animal body, into fat, rendered it quite probable that similar agencies operating in the animal system could produce the animal fats from non-nitrogenous, as well as from nitrogenous, constituents of the vegetable food consumed.

These teachings of Liebig were at first received with much opposition, yet they are to-day still held worthy of the most serious consideration. The subsequent careful investigations of Dumas, Persoz, Bousingault, Lawes and Gilbert, and others, confirm the insufficiency of the fats contained in the food consumed, to account for the exceptionally large accumulation of fat in many successful and economical cases of stock fattening.

The same experimenters recognize also the beneficial influence of a liberal supply of nitrogenous food wherever an alteration of starch or sugar into fats has to be assumed to explain an exceptional accumulation of that substance in the animal system. One of the best authorities in practical stock-feeding of to-day (J. Kühn) states without reserve, in his late advice to farmers, that wherever the fodder contains a liberal supply of starch or of sugar, they may be considered an offset for a deficiency in fat.

The real weakness in Liebig's views regarding the origin of fats in animals consists more in the fact that we are not yet able to give a satisfactory explanation regarding the precise chemical or physiological process which changes the free, fatty acids produced from starch and sugar into the neutral fats (glycerides, *i. e.*, combination of the well-known substance, glycerine), than that practical experience disproves the assumptions. Physiologists and physiological chemists of to-day recognize almost without exception the important relations which exist between a liberal supply of sugar and starch in the animal diet and the actual accumulation of fat in the animal system; yet they differ more or less as far as their special mode of action is concerned. Some investigators believe with Liebig, for good scientific reasons, in a direct conversion of sugar and starch into animal fat, leaving the actual proof confidently to future developments. Others deny the actual change of both substances into animal fat; they ascribe to them merely the functions of protecting the fat contained in the fodder, and the fat produced from the nitrogenous constituents of the vegetable food whilst passing through the animal system against the oxydizing influence of the air during the process of respiration. (Voit.)

The beneficial influence of a rich nitrogenous diet on the products of the dairy is frequently mentioned as a substantial proof in that direction.

All non-nitrogenous constituents of the food, the fat included, yield to the oxidizing influence of the air and produce the same compounds, namely, carbonic acid and water, whether burned in the open air, or during their circulation through the animal body. As they support the process of respiration, Liebig called them the respiratory or heat-producing constituents of the animal food; he ascribed the entire production of the organic animal heat to a chemical process, and assigned to the non-nitrogenous substances no other ultimate functions but to produce heat; the amount of carbonic acid and water produced became the direct expression of the consumption of oxygen from the air during the process of respiration.

These statements are to-day still considered satisfactory in their general application. Chemical reactions are considered the source of animal heat and of animal energy.

III.—Mineral Constituents of the Food.

(Lime, potassa, soda, magnesia, iron, sulphur, phosphorus, chlorine, etc.)

The relations of the mineral constituents of the animal body to the life of animals were not better understood before 1840 than those found in plants to the life of plants. Liebig's well-known extensive investigations concerning the functions of certain mineral substances in the growth of plants, induced him to study their relations to animal life. He compared the mineral constituents of the food consumed with those found in the animal body; he studied the distribution of the various mineral elements throughout the different organs of the body and within the secretions and the excretions of the animals on trial. In the course of these investigations he noticed the alkaline reaction of the blood, found the soda the principal alkali in the blood and in the bile, and the potassa in the flesh, and recognized the hydrochloric acid as a constituent of the liquid of the stomach.

These and similar important results caused him to assert, for the first time in the history of animal physiology, that a definite supply of certain mineral substances is indispensable for the continuation of life. His special views may be gleaned from the following personal statement.

"The inorganic or saline substances which form the constant constituents of the blood, of the flesh, of the muscles and of every other organ, exert an important and, in many instances, even a controlling influence on the process of animal respiration, digestion, assimilation, secretion and excretion. They impart to the organic portion of the food, the power of supporting animal life; without them no food is complete."

Actual experience has fully confirmed his statements. To feed merely the mineral constituents of the fodder articles is equal to starvation, and to deprive the normal animal food of its essential mineral constituents before feeding it carries with it the destruction of life wherever such material is exclusively fed. Judging from experience in plant growth, it seems but reasonable to assume that in compounding fodder rations for our various kinds of farm animals the mineral constituents of the fodder should be properly supplemented, if necessary, to meet the special wants of the animal.

The previous short sketch of Liebig's experimental investigations regarding the requirements of a complete animal diet cannot fail to show that his demonstration of the necessity to compound fodder rations with reference to three distinctly differing groups of plant constituents has given us a more concise idea concerning the process of animal nutrition, and thereby furnished us with a safer basis for studying the feeding effect of our farm crops.

The extensive practical chemical work which has furnished him with the material for his conclusion regarding the process of animal digestion, assimilation, respiration, etc., and the dependency of the animal food on the constituents of plants, is largely due to the careful scientific labors of many other eminent scientists; the comprehensive interpretation of their results are essentially his own.

Chemical physiology, as a distinct field of scientific research, originated with Liebig; yet it is equally true that some of the first and of the most important chemical physiological investigations are due to distinguished pioneers in comparative anatomy and modern physiology, — J. V. Müller and others, contemporaries of him.

A characteristical statement of Liebig regarding the relation which exists between the vegetable and the animal kingdom may close this chapter.

"A comprehensive law of nature connects the development of the organs of an animal, its growth and its increase in weight with the consumption of certain substances, which are identical with the principal constituents of its blood; it is manifest that the animal organism produces its blood only as far as its form is concerned; and, also, that nature has denied to it the power to produce it out of other substances, which are not identical with the principal constituents of its blood.

"The animal body is a higher organism, which begins its development with those materials with which the life of the ordinary fodder plant usually terminates. As soon as the fodder crops and the grain crops have produced their seeds, they die; with the production of the fruit, a period of life in the case of the perennial plant ends; in the innumerable series of organic compounds, which begin with the inorganic articles of plant food, to the most complicated constituents of the brain of the animal, we cannot notice a break nor an interruption. The constituent of the animal food which produces the principal part of its blood, is the product of the vital activity of the plant."

Having attempted in preceding pages to show the important influence which chemistry has exerted on the development of a more concise idea of what constitutes a complete article of animal diet, from a physiological standpoint, *i. e.*, regarding its special fitness to sustain the life of animals, I propose to point out briefly the effect which the above-stated information has had on the rational agricultural practice of to-day.

The recognition of the physiological fact, that no single constituent of a plant can support animal life for any length of time, — neither nitrogenous matter, nor fat, sugar or starch, nor mineral matter; but that certain proportions are required of each of the three principal groups of substances previously described, induced chemists to study more closely the various farm plants with particular reference to the relative proportion, and to the special quality of their proximate constituents.

The results obtained in this connection soon revealed the fact, that not two kinds of plants, or even parts of plants, are of an identical composition. It became soon apparent that the composition of one and the same plant even differs widely not only at the various stages of growth and maturity, but also when raised in a different climate and upon a different kind of soil, as well as in case of a varying system of manuring and of cultivation. Whilst it could not be denied that the character and the quality of each farm plant became soon much better known, and that actual feeding experiments carried on with a due consideration of a more exact chemical examination of the particular kind of fodder consumed, had afforded a safer basis for final conclusions, it became not less evident in the course of time, that the chemical analysis of an article of fodder alone did not suffice to decide the comparative feeding value of different kinds of farm plants, or even of the same plants in different stages of growth. The chemical analysis of the time had furnished most valuable information regarding the general character of many of our fodder plants as far as the quality and the quantity of their proximate organic constituents are concerned, yet it had not given all the information needed to pronounce upon their exact feeding value.

As only that part of the food consumed can participate in the process of animal nutrition, which, by the aid of the secretion of the digestive organs enters into solution and subsequent circulation through the animal system, it is but natural that the rate of digestibility of our prominent farm crops in various stages of growth, as well as in case of various kinds of farm animals, could not fail to engage the attention of agricultural chemists.

They directed their efforts in two directions:

First, they improved their mode of analyzing fodder substances. The alterations were made with a view to secure analytical results which would closer correspond with the rates of digestibility noticed in actual feeding experiments. Since 1860, one mode has been used in the majority of fodder analyses (Henneberg, Stohmann, Heiden). The advantage of this course consists in the fact that all analyses since that year have a strictly comparative value, as far as the new results are concerned.

Second, new feeding experiments were carried on with the direct purpose to ascertain by competent hands the actual transformation which the different constituents of the fodder plants suffered by their passage through the system of different kinds of farm stock.

A lately published compilation of carefully conducted feeding experiments (E. Wolff in Mentzel's and Lengerke's Kalender 1882, I Bd. '83) shows that one hundred and eighty-two articles of fodder have thus far been tested, regarding their digestibility; seventy-eight experiments were carried on with cattle, three hundred and ninety-four with sheep, twenty with goats, thirty-five with horses, and ~~four~~ to ~~five~~ 40-50 with swine. The subsequent tabular statement of feeding experiments by Julius Kühn in Halle, 1880, is not without interest in this connection as a matter of reference.

The first table contains the analyses of the different articles of fodder fed during the experiments recorded in the second table. The highest and the lowest results of their analyses are stated for the particular purpose of calling the attention of practical farmers to the important fact that the quality of their crops deserves the most serious consideration in a rational system of stock-feeding. The influence of the condition of the lands, as far as manuring is concerned, and the particular system of cultivation on the composition of the crops, is far more serious than generally assumed.

The second table (page 24) states the rates of digestibility, in percentages, of each group of essential constituents of the fodder articles which served in the recorded experiments. The highest and the lowest rates are stated, to convey some approximate idea regarding the influence which the condition of the fodder and the individuality of the animal may exert on the digestibility of the particular constituents of the former.

TABLES.

I.— *Percentage of the Composition of Food Materials, with which Experiments have been Made on Animals to Determine their Digestibility.*

KIND OF FOOD MATERIAL.	DRY SUBSTANCE AFTER REMOVAL OF MOISTURE.			ALBUMINOIDS.			FAT-OIL.			CARBO-HYDRATES.			WOODY FIBRE.			ASH.
	Lowest.	Highest.	Average.	Lowest.	Highest.	Average.	Lowest.	Highest.	Average.	Lowest.	Highest.	Average.	Lowest.	Highest.	Average.	Average.
I.— GREEN FOODS.																
1. Meadow grass,	22.0	40.5	29.2	1.9	4.0	2.6	0.3	1.1	0.70	8.4	15.4	11.7	7.00	16.3	12.1	2.1
2. Pasture grass,	12.4	48.1	25.0	1.6	6.0	3.0	0.3	1.5	0.80	3.5	22.8	13.1	3.12	17.0	6.0	2.1
3. Clover from pasture,	16.4	20.3	19.8	3.5	4.5	4.0	0.8	0.9	0.85	7.2	9.8	8.0	5.20	6.0	5.6	1.4
4. Clover,	13.6	31.9	19.8	2.2	6.2	3.6	0.4	1.6	0.70	4.2	15.1	8.5	3.40	11.0	5.6	1.4
5. Lucerne,	16.5	30.1	24.7	2.8	7.3	4.5	0.5	0.9	0.70	6.0	14.4	8.4	3.5	13.4	9.3	1.8
6. Sainfoin,	20.0	23.4	21.5	3.2	4.3	3.5	0.6	0.9	0.70	8.2	10.8	8.5	5.8	12.9	7.6	1.2
7. Common vetch,	15.7	19.4	18.0	2.7	4.7	3.7	–	–	0.60	4.5	12.7	6.1	3.9	10.0	6.0	1.6
8. Lupines,	10.6	16.1	14.3	2.4	4.2	3.1	0.2	0.4	0.30	4.0	7.3	6.2	1.4	5.1	4.0	0.7
9. Potato vines,	–	–	22.0	–	–	2.3	–	–	1.00	–	–	9.7	–	–	6.0	3.0

10. Fodder corn,	13.2	23.2	16.0	0.9	2.2	1.4	0.2	0.8	0.50	5.8	15.3	8.4	3.0	5.9	4.7	1.0
11. Sorghum,	15.9	37.1	28.7	2.5	5.9	4.4	0.8	1.5	1.10	6.0	16.2	12.1	4.6	11.6	9.2	1.9
12. Leaves of poplar,	34.2	45.0	38.9	2.8	8.0	5.2	–	–	1.50	5.2	33.1	15.2	6.0	22.9	13.0	4.0
II. — VARIETIES OF HAY.																
13. Meadow hay,	78.3	90.2	85.7	5.8	19.4	9.5	1.2	5.6	2.3	22.6	50.7	40.3	19.7	39.9	27.1	6.5
14. Rowen,	79.8	88.2	85.7	8.4	18.5	11.7	2.3	6.8	3.1	33.3	49.7	42.3	19.0	30.7	22.0	6.6
15. Clover hay,	77.1	90.0	83.3	7.2	15.8	11.0	1.2	5.5	3.2	22.3	39.7	32.9	19.5	43.0	29.9	6.3
16. Lucerne hay,	80.8	87.5	83.8	13.1	19.7	14.4	2.3	3.8	2.5	20.0	34.8	27.9	19.3	40.0	33.0	6.0
17. Sainfoin hay,	83.3	88.2	85.1	12.8	17.1	13.3	–	–	2.5	34.2	34.7	34.5	27.1	30.9	29.0	5.8
18. Hay of common vetch,	83.3	85.7	85.1	14.2	20.4	17.6	2.1	2.50	2.3	28.5	32.8	29.7	23.5	29.5	26.5	9.0
19. Hay of lupines,	74.1	90.9	86.1	6.0	23.5	16.0	1.1	2.9	2.2	28.1	31.2	29.5	23.0	48.3	32.6	5.8
20. Dried potato vines,	85.0	95.3	90.0	5.7	12.9	9.4	1.2	3.6	2.4	33.0	38.6	34.6	22.7	36.6	32.0	11.6
21. Ensilage of beet leaves,	20.0	26.8	23.4	0.94	3.0	1.9	0.75	1.2	1.0	8.6	9.0	8.8	2.0	2.7	2.3	9.4
III. — STRAW.																
22. Wheat straw,	74.0	91.9	85.7	1.4	5.6	3.1	0.6	2.0	1.2	26.1	44.4	37.5	28.9	52.6	40.0	3.9
23. Rye straw,	81.4	89.7	85.7	1.5	4.6	3.0	1.1	2.5	1.3	23.4	44.5	33.3	30.1	54.9	44.0	4.1
24. Oat straw,	78.8	89.7	85.7	1.3	7.0	4.0	1.0	5.1	2.0	24.9	48.9	35.6	30.0	50.2	39.7	4.4
25. Barley straw,	82.5	89.1	85.7	1.9	5.4	3.4	1.1	2.04	1.4	18.2	45.5	34.7	34.4	54.0	41.8	4.4

Percentage of the Composition of Food Materials — Continued.

KIND OF FOOD MATERIAL.	DRY SUBSTANCE AFTER REMOVAL OF MOISTURE.			ALBUMINOIDS.			FAT-OIL.			CARBO-HYDRATES.			WOODY FIBRE.			ASH.
	Lowest.	Highest.	Average.	Lowest.	Highest.	Average.	Lowest.	Highest.	Average.	Lowest.	Highest.	Average.	Lowest.	Highest.	Average.	Average.
26. Bean straw,	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
27 and 28. Pea straw,	78.0	85.5	82.5	3.3	16.4	9.9	0.7	2.2	1.5	16.9	33.8	31.8	25.8	41.7	33.5	5.8
28. Lupine straw,	85.8	89.7	87.4	4.9	6.2	5.5	1.1	1.5	1.3	33.2	35.6	34.2	37.5	40.9	39.5	5.3
IV. — GRAINS.																
29. Oats,	83.6	92.4	86.3	6.3	18.5	12.0	4.4	7.3	6.0	48.0	71.8	56.6	4.1	16.1	9.0	2.7
30. Barley,	79.1	91.7	86.2	6.2	18.3	11.2	1.0	3.2	2.1	56.1	74.7	65.5	2.2	10.8	5.2	2.2
31. Corn,	77.6	91.8	87.3	5.8	15.1	10.6	1.5	9.2	6.5	52.4	72.7	65.7	1.3	8.5	2.8	1.7
32. Beans,	80.3	88.3	85.9	21.4	28.2	25.1	1.2	2.5	1.6	42.8	55.4	46.7	3.7	12.	9.4	3.1
33. Pease,	77.9	91.1	86.8	18.6	27.1	22.4	0.6	5.3	3.0	41.9	59.6	52.6	1.9	9.2	6.4	2.4
34. Lupines,	82.4	90.6	87.2	28.3	43.4	35.4	3.7	7.9	5.3	20.2	36.4	29.2	11.4	17.5	13.8	3.5
V. — TECHNICAL PRODUCTS AND BY PRODUCTS.																
35. Rapeseed cake,	80.8	98.2	88.5	17.9	45.5	31.6	4.4	18.8	9.6	7.4	41.6	29.3	1.3	28.4	11.0	7.0

36. Linseed cake, ...	81.1	92.9	87.8	20.6	37.8	29.5	6.0	18.2	10.0	19.7	41.3	29.8	5.1	16.8	9.7	8.8
37. Palm-nut meal, ...	81.9	93.4	89.2	11.7	23.9	18.5	1.1	7.3	3.3	22.4	52.5	41.7	11.7	39.7	21.7	4.0
38. Palm-nut cake, ...	85.6	93.3	89.5	10.7	24.7	16.9	6.8	29.3	12.0	17.9	52.0	39.0	9.9	30.7	17.4	4.2
39. Cocoanut cake, ...	87.9	94.0	90.6	16.3	37 2	20.6	6.9	22.7	13.2	28.4	47.4	37.4	7.5	21.1	14.2	5.2
40. Cotton-seed cake, ...	85.8	93.4	90.0	18.2	28.3	23.5	5.1	9.8	6.6	26.5	36.7	32.0	17.0	27.0	21.1	6.8
41. Wheat bran, ...	83.5	92.4	87.0	10.1	27.0	14.5	1.7	6.6	3.5	28.5	61.5	53.6	4.1	31.6	9.4	6.0
42. Spelt bran, ...	86.0	87.0	86.5	13.8	16.1	14.6	3.0	5.3	4.1	51.6	54.9	53.3	8.1	9.8	8.9	15.6
43. Rye bran, ...	81.6	93.5	87.5	10.1	18.1	14.5	1.9	5.0	3.5	32.9	64.6	57.1	4.2	28.5	7.2	5.2
44. Skimmed milk (sour), ...	7.6	11.5	10.0	2.5	4.9	3.5	0.3	1.4	0.7	3.1	6.1	5.0	–	–	–	0.5
45. Meat flour, ...	86.4	90.9	88.5	46.0	74.7	72.8	1.2	13.2	12.0	–	–	–	–	–	–	3.7
46. Norwegian fish-guano, ...	–	–	87.4	–	–	49.0	–	–	1.8	–	–	–	–	–	–	36.6
47. May bogs, ...	–	–	99.6	–	–	18.8	–	–	3.7	–	–	–	–	–	4.8	6.7

II. — *Digestibility of Fodder Plants and of Technical Products Actually Experimented with.*

THE DIGESTIBLE COMPONENT PARTS IN PER CENT.

KINDS OF FOOD MATERIAL.	ALBUMINOIDS.			FAT OR OIL.			CARBO-HYDRATES.			WOODY FIBRE.		
	Lowest.	Highest per-centage.	Average.	Lowest.	Highest per-centage.	Average.	Lowest.	Highest per-centage.	Average.	Lowest.	Highest per-centage.	Average.
I. — GREEN FOODS.												
1. Meadow grass,	70.6	79.3	75.0	63.4	68.1	66.0	74.5	84.4	79.0	70.3	75.2	73.0
2. Pasture grass, good quality,	69.0	71.7	70.0	60.4	68.1	65.0	74.7	84.4	79.0	65.4	72.8	69.0
3. Clover from pasture,	77.7	78.7	78.0	63.3	65.1	64.0	78.0	78.5	78.0	66.9	67.4	67.0
4. Clover, red variety, shortly before flowering,	70.5	74.3	73.0	57.0	65.2	62.0	69.6	83.2	76.0	50.1	60.4	55.0
at the beginning,	71.7	76.3	74.0	66.1	75.3	71.0	73.0	80.1	77.0	52.2	59.2	56.0
in full bloom,	64.7	70.2	67.0	58.6	65.4	63.0	68.3	72.6	70.0	46.4	50.1	48.0
at the end,	56.4	60.8	59.0	42.2	46.7	45.0	70.3	71.0	71.0	38.3	39.3	39.0
5. Lucerne (before and at beginning of flowering),	78.2	83.2	81.0	37.0	53.6	45.0	61.1	76.9	72.0	31.6	46.8	41.0
6. Sainfoin,	71.7	73.3	73.0	64.1	69.2	67.0	76.5	80.0	78.0	42.1	42.3	42.0
7. Common vetch,	73.0	80.0	76.0	50.0	65.8	60.0	63.3	76.3	65.0	51.2	58.3	54.0
8. Lupines,	73.0	75.7	74.0	15.5	45.3	30.0	57.3	65.9	62.0	67.1	79.8	73.0
9. Potato vines, beginning of October,	–	–	42.0	–	–	24.0	–	–	60.0	–	–	36.0
10. Fodder corn,	–	–	73.0	–	–	75.0	–	–	67.0	–	–	72.0

11. Sorghum,	–	–	62.0	–	–	85.0	–	–	78.0	–	–	60.0
12. Leaves of poplar,	–	–	56.0	–	–	79.0	–	–	65.0	–	–	35 0
II. — VARIETIES OF HAY.												
13. Meadow hay,	38.9	71.0	57.0	8.5	69.7	46.0	48.0	78.8	63.0	44 6	72.4	58.0
14. Grummet,	53.0	68.0	61.0	27.0	57.4	46.0	56.7	75.0	66.0	54.3	74.9	63.0
15. Clover hay,	43.0	73.3	60.0	33.0	75.3	59.0	62 5	80.1	69.0	38.0	59.2	47.0
16. Lucerne hay, excellent quality,	72.1	83.0	77.0	29.7	51.0	39.0	52.6	72.0	65.0	33.1	45.7	40 0
17. Sainfoin hay (very carefully dried),	69.7	70.2	70.0	65.1	67.4	66.0	73.6	75.0	74.0	33.3	39.4	36.0
18. Hay of common vetch,	73.0	80.0	76.0	50.0	65.8	60.0	63.3	67.3	65.0	51.2	58 3	54.0
19. Hay of lupines,	73.0	75.7	74.0	15.5	45.3	30.0	57.3	65.9	62.0	67.1	79.8	73.0
20. Dried potato vines,	–	–	42.0	–	–	24.0	–	–	60.0	–	–	36.0
21. Ensilage of beet leaves,	–	–	65.0	–	–	60 0	–	–	54.0	–	–	54.0
III. — STRAW.												
22. Wheat straw,	–	–	26.0	–	–	27.0	–	–	40.0	–	–	52.0
23. Rye straw,	2 6	82.6	25.0	21.2	40.9	32.0	28.5	51.8	36.0	46 8	72 9	56.0
24. Oat straw,	14.4	50.0	38.0	14.0	51.0	30.0	32.2	47.0	42.0	53.0	67.0	61.0
25. Barley straw (poor quality),	12 8	16.8	15.0	32.4	42.6	38.0	50.7	51.3	51.0	49.1	55.6	52.0
26. Bean straw,	49.0	55.0	51.0	50 0	60.0	55.0	57.0	64.0	61.0	33.0	39.0	36.0
27. Pea straw (very good),	60.3	60.6	60.5	41.6	50.1	46.0	64.0	64.8	64.0	47.2	55.9	52.0
28. Lupine straw,	35.4	39.7	37.0	25.4	35.0	30.0	64.5	65.4	65.0	49.2	52.0	51.0

Digestibility of Fodder Plants and of Technical Products, etc. — Concluded.

KINDS OF FOOD MATERIAL.	ALBUMINOIDS.			FAT OR OIL.			CARBO-HYDRATES.			WOODY FIBRE.		
	Lowest.	Highest per-centage.	Average.	Lowest.	Highest per-centage.	Average.	Lowest.	Highest per-centage.	Average.	Lowest.	Highest per-centage.	Average.
IV. — GRAINS.												
29. Oats (tested on ruminants),	58.0	81.3	74.0	68.4	99.0	82.0	65.0	79.7	73.0	5.5	32.1	21.0
30. Barley (ground, tested on ruminants),	–	–	77.0	–	–	100.0	–	–	87.0	–	–	20.0
Barley (ground, tested on pigs),	74.6	80.7	78.0	58.2	77.3	69.0	89.3	91.3	90.0	14.4	27.4	20.0
31. Corn (ground, tested on pigs),	83.9	88.1	85.0	74.4	78.5	76.0	92.5	93.3	94.0	17.0	57.4	34.0
32. Beans (ground, tested on ruminants),	80.6	100.0	90.0	86.9	100.0	97.0	90.7	98.7	94.0	25.1	100.0	63.0
33. Pease (only tested on pigs),	84.4	91.5	88.0	45.0	69.0	58.0	94.7	98.6	97.0	55.1	88.5	74.0
34. Lupines (tested on sheep),	95.5	97.6	97.0	–	–	100.0	77.0	100.0	90.0	–	–	–
V. — TECHNICAL PRODUCTS, ETC.												
35. Rapeseed cake (tested on cows and steers),	81.3	92.4	85.4	79.7	93.6	88.0	70.2	84.9	78.0	0.0	34.3	11.0
The same (tested on sheep),	65.3	83.9	75.9	59.8	77.2	69.0	66.0	85.4	78.0	0.0	5.5	3.0
36. Linseed cake (tested on steers),	80.2	89.9	87.0	86.7	93.9	91.0	85.0	96.3	91.0	–	54.5	26.0
The same (tested on goats and sheep),	80.0	87.4	83.0	86.5	92.5	90.0	60.0	78.7	71.0	29.7	92.9	62.0
37–38. Palm-nut meal and palm-nut cake (tested on ruminants),	95.0	100.0	98.0	95.0	100.0	98.0	92.0	96.0	94.0	72.2	92.0	82.0

39. Cocoanut cake (tested on pigs),	72.7	74.2	74.0	81.8	84.6	83.0	87.3	81.2	89.0	54.7	66.0	60.0
40. Cotton-seed cake (tested on sheep),	69.4	78.0	74.0	83.3	100.0	91.0	37.6	54.7	46.0	7.1	36.2	23.0
41. Wheat bran (dry, fed to steers),	82.9	93.5	88.0	77.6	81.6	80.0	77.7	81.2	80.0	16.9	32.2	20.0
The same variously prepared — boiled, fermented, etc. (fed to steers),	61.6	81.0	70.0	68.8	89.9	81.0	69.7	82.1	75.0	3.5	21.5	13.0
The same (tested on sheep),	–	–	75.0	–	–	50.0	–	–	70.0	–	–	37.0
42. Spelt bran (tested on sheep),	65.5	85.2	73.0	81.3	93.8	88.0	81.3	100.0	91.0	1.21	100.0	?
43. Rye bran (tested on pigs),	65.8	66.2	66.0	57.4	57.6	57.5	74.7	74.5	74.5	6.5	10.5	9.0
44. Skimmed milk, sour (tested on pigs),	–	–	96.0	–	–	95.0	–	–	99.0	–	–	–
45. Meat flour (tested on ruminants),	–	–	95.0	–	–	98.0	–	–	–	–	–	–
The same (tested on pigs),	95.1	98.9	97.0	82.3	90.7	87.0	–	–	–	–	–	–
46. Norwegian fish-guano (tested on ruminants),	–	–	90.0	–	–	76.0	–	–	–	–	–	–
47. May-bogs (tested on pigs),	70.9	81.0	77.0	78.8	91.8	83.0	–	–	–	–	–	–

These tabular statements show that the particular stage in the growth of a fodder plant exerts not only a controlling influence on its composition, but also on the rate of digestibility of its various organic constituents; and they prove also that the same group of organic constituents behave differently in that direction, not only in case of different plants, but also in case of different parts of the same plant. A few observations may illustrate these facts:—

1. Rate of Digestibility of Nitrogenous Constituents.

	Per cent.		Per cent.
Corn,	85	Oats,	74
Wheat bran,	70	Rye bran,	66
Wheat straw,	26	Oat straw,	38
Meadow hay,	57	Rowen,	61
Green maize,	73	(Stover,	26?)
Green clover, just before blooming,			73
Green clover, in full bloom,			67
Green clover, at the close of blooming,			59

2. Rate of Digestibility of Fats.

	Per cent.		Per cent.
Corn,	76	(Stover,	28?)
Oats,	82	Oat straw,	30
Barley,	100	Wheat straw,	27
Green corn,	75		

3. Rate of Digestibility of Non-nitrogenous Extract Matter.

	Per cent.		Per cent.
Corn,	94	Green corn,	67
Oats,	73	(Stover,	40?)
Potatoes,	100		

4. Rate of Digestibility of Crude Vegetable Fibre.

	Per cent.		Per cent.
Corn,	34	Stover,	52
Oats,	21	Oat straw,	61
Barley,	20	Barley straw,	52

(Cattle, 70 per cent., horses, 25 per cent., swine, 10 per cent.)*

Adding to these results the facts, that these rates of digestibility vary more or less in case of different kinds of animals, it is quite obvious, that no single plant can furnish a proper standard for the valuation of the various fodder sub-

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* Approximations.

stances, nor can one definite number state correctly their relative feeding value. A former practice of agriculturists to consider a good meadow hay the standard crop for a determination of the relative or absolute feeding value of other crops rests largely on a misconception, for it confounds the market price of the article with its feeding value.

The value of an article of fodder may be stated from two distinctly different standpoints, namely:

1. From an economical standpoint, its cost or market price; and

2. From a physiological standpoint, its feeding effect or nutritive value.

1. The market price of our fodder articles depends on the supply and the demand in the general market; its determination is beyond the control of the individual farmer. The market price of hay of the same quality may vary widely in different years and in different localities; its feeding value remains materially the same, under corresponding circumstances, year after year.

The chemical analysis of fodder crops has been turned to account to ascertain their comparative approximate market value in a similar way as the analysis of commercial fertilizers, by assigning to each class of their principal food constituents, as far as their digestible portion is concerned, a value deduced from its costs in a leading fodder crop of a good average quality. The ton price in principal depots serves best for that purpose, and the calculated price refers to similar market conditions; the proper retail price may be best determined in each locality with proper consideration of its facilities of market, transportation, etc. This practice which has been of late introduced into Germany, has the advantage of telling us whether any particular lot of a fodder article is cheap or not, at the price we are asked for it, and whether the present price of a commercial article of fodder is a fair one or an extraordinary one; it also can teach us, after a careful consideration of our home resources of fodder, what particular commercial fodder material would best supplement our stock of fodder on hand, to benefit our special farm industry. According to present rules, nitrogenous fodder constituents and fat are counted about five times as high as the non-nitrogenous extract matter and the digestible cellulose substance. German agricultural chemists allow four and one-third cents per pound of digestible nitrogeneous food constituents and fat, and nine-tenths of a cent per pound of digestible non-nitrogenous extract matter and cellular substance. Whether this basis will prove to be the most judicious one for our circumstances, experience will soon decide; for my present purpose, namely, to illustrate the application of the chemical analysis as a means to ascertain the relative, comparative money value of several varieties of corn, etc., the German values are applicable:

I.	Canada Dutton Corn, ...	$1.13¾	per 100 lbs.
II.	Canada Dutton Corn, ...	1.09¾	"
III.	Crosby Sweet Corn, ...	1.15¾	"
IV.	Blue Texas Sweet Corn, ...	1.24¾	"
V.	Wheat Bran (shorts), ...	21.04	per ton.
VI.	Canada Dutton Corn, ...	22.13	"
VII.	Cotton-Seed Cake, ...	–	
	Decorticated, ...	39.29	per ton.

I. — *Canada Dutton Corn, No. 1.*

Digestible ratio, .	–	76 pr. ct.	85 pr. ct.	94 pr. ct.	34 pr. ct.	–
Value per lb., . .	–	4⅓ cents.		.9 cent.		–
	Moisture.	Fat.	Nitrogenous Matter (Albuminoids.)	Non-Nit. Extract Matter.	Cellulose.	Ash.
100 lbs., . . .	15.0000	4.4835	11.7954	65.0985	2.3602	1.2664
Digestible, . . .	–	3.409	10.030	61.195	.80	–
75 lbs., . . .	11.2500	3.3627	8.8467	48.8238	1.7703	.9498
Digestible, . .	–	2.5560	7.5225	45.8970	.60	–
50 lbs., . . .	7.5000	2.2418	5.8978	32.5492	1.1802	.6332
Digestible, . . .	–	1.7040	5.0150	30.5980	.40	–
25 lbs., . . .	3.2500	1.1209	2 9489	16.2746	.5901	.3166
Digestible, . . .	–	.8520	2.5075	15.2990	.20	–
Actual value of digestible matter in 100 lbs.		15 cts.	43 cts.	55 cts.	¾ ct.	
		Total, — $1.13¾ per 100 lbs.				

II. — *Canada Dutton Corn, No. 2.*

Digestible ratio, .	–	76 pr. ct.	85 pr. ct.	94 pr. ct.	34 pr. ct.	–
Value per lb., . .	–	4⅓ cents.		.9 cent.		–
	Moisture.	Fat.	Nitrogenous Matter (Albuminoids.)	Non-Nit. Extract Matter.	Cellulose.	Ash.
100 lbs., . . .	15.0000	4.9600	10.2445	66.0840	2.3602	1.3513
Digestible, . . .	–	3.7680	8.7200	62.1160	.80	–
75 lbs., . . .	11.2500	3.7200	7.6833	49.5630	1.7703	1.0134
Digestible, . . .	–	2.826	6.5400	46.5870	.60	–
50 lbs., . . .	7.5000	2.4800	5.1222	33.0420	1.1802	.6756
Digestible, . . .	–	1.8840	4.3600	31.0580	.40	–
25 lbs., . . .	3.7500	1.2400	2.5611	16.5210	.5901	.3378
Digestible, . . .	–	.9420	2.1800	15.5290	.20	–
Actual value of digestible matter in 100 lbs.		15 cts.	37½ cts.	56 cts.	¾ ct.	
		Total, — $1.09¼ per 100 lbs.				

III. — *Crosby Sweet Corn.*

Digestible ratio, .	–	76 pr. ct.	85 pr. ct.	94 pr. ct.	34 pr. ct.	–
Value per lb., . .	–	4⅓ cents.		.9 cent.		–
	Moisture.	Fat.	Nitrogenous Matter (Albuminoids.)	Non-Nit. Extract Matter.	Cellulose.	Ash.
100 lbs., . . .	15.0000	6.4372	10.8096	63.7984	2.3155	.6394
Digestible, . . .	–	4.8900	9.1900	60.0600	.7	–
75 lbs., . . .	11.2500	4.8279	8.1072	47.8488	1.7367	1.2297
Digestible, . . .	–	3.6600	6.9000	45.0500	.60	–
50 lbs., . . .	7.5000	3.2186	5.4048	31.8992	1.1578	.8198
Digestible, . . .	–	2.4400	4.6000	30.0400	.40	–
25 lbs., . . .	3.7500	1.6093	2.7024	15.9496	.5789	.4099
Digestible, . . .	–	1.2200	2.3000	15 0200	.20	–
Actual value of digestible matter in 100 lbs.		21 cts.	40 cts.	54 cts.	¾ ct.	
		Total, — $1.15¾ per 100 lbs.				

IV. — *Blue Texas Sweet Corn.*

Digestible ratio,	–	76 per ct.	85 pr. ct.	94 pr. ct.	34 pr. ct.	–
Value per lb.,	–	4⅓ cents.		.9 cent.		–
	Moisture.	Fat.	Nitrogenous Matter (Albuminoids.)	Non-Nit. Extract Matter.	Cellulose.	Ash.
100 lbs.,	15.0000	8.0156	12.7645	60.4038	2.3602	1.4559
Digestible,	–	6.0920	10 8520	56.7530	.80	–
75 lbs.,	11.2500	6.0117	9.5733	45.3030	1.7703	1.0920
Digestible,	–	4 5690	8.1390	42.5640	.60	–
50 lbs.,	7.5000	4.0078	6.3822	30.2020	1.1802	.7280
Digestible,	–	3.0460	5.4260	28.3760	.40	–
25 lbs.,	3.7500	2.0039	3.1911	15.1010	.5901	.3640
Digestible,	–	1.5230	2.7130	14.1880	.20	–
Actual value of digestible matter in 100 lbs.		26 cts.	47 cts.	51 cts.	¾ ct.	
		Total, — $1.24¾ per 100 lbs.				

V. — *Nutritive Ratio, 1 : 4.14.*

Shorts or Wheat Bran, (Average analysis.)	Percentage Composition.	Constituents (in lbs.) in a ton of 2,000 lbs.	Pounds digestible in a ton of 2,000 lbs.	Value per ton 2,000 lbs.
Water,	15.0000	300.00	–	–
Fat,	3.4195	68.39	54.71	$2.37
Nitrogenous matter,	14.1667	283.33	249.33	10.80
Non-nitrogenous extract matter,	52.3678	1047.35	837.88	7.54
Cellulose,	9.1839	183.68	36.73	.33
Ash,	5.8621	117.25	–	–
	100.0000 pr. ct.	2000.00 lbs.	1178.65 lbs.	$21.04

	Fat.	Nitrogenous Matter.	Non-nitrogenous Matter.	Cellulose.
Digestible ratio,	80 per cent.	88 per cent.	80 per cent.	20 per ct.
Value per lb.,	4⅓ cents.		.9 cent.	

VI. — *Nutritive Ratio. 1:8.3.*

Canada Dutton Corn, No. 2.	Percentage Composition.	Constituents (in lbs.) in a ton of 2.000 lbs.	Pounds digestible in a ton of 2.000 lbs.	Value per ton 2.000 lbs.
Water,	15.0000	300.00	–	–
Fat,	4.9600	99.19	75.39	$3.27
Nitrogenous matter,	10.2445	204.89	174.15	7.54
Non-nitrogenous extract matter,	66.0840	1321.68	1242.37	11.18
Cellulose,	2.3602	47.22	16.06	.14
Ash,	1.3513	27.02	–	–
	100.0000 pr. ct.	2000.00 lbs.	1507.97 lbs.	$22.13

	Fat.	Nitrogenous Matter.	Non-nitrogenous Matter.	Cellulose.
Digestible ratio,	76 per cent.	85 per cent.	94 per cent.	34 per ct.
Value per lb.,	4½ cents.		.9 cent.	

VII. — *Nutritive Ratio, 1:1.57.*

Cotton Seed Meal. (Decorticated.)	Percentage Composition.	Constituents (in lbs.) in a ton of 2,000 lbs.	Pounds digestible in a ton of 2,000 lbs.	Value per ton 2,000 lbs.
Water,	15.00	300.00	–	–
Fat,	13.11	262.20	235.40	$10.20
Nitrogenous matter,	37.14	742.80	598.60	25.94
Non-nitrogenous extract matter,	18.66	373.20	350.20	3.15
Cellulose,	8.82	176.40		
Ash,	7.27	145.40	–	–
	100.00 pr. ct.	2000.00 lbs.	1184 20 lbs.	$39.29

	Fat.	Nitrogenous Matter.	Non-nitrogenous Matter.
Digestible ratio,	90 per cent.	81 per cent.	64 per cent.
Value per lb ,	4½ cents.		.9 cent.

II. The Physiological or Nutritive value of an article of Food refers to its actual Feeding effect.

The market value and the actual feeding effect of one and the same article do not *necessarily correspond* with each other; in fact, they *rarely coincide.*

The market value may be stated for each locality by one definite number. The feeding effect of one and the same substance, simple or compound, varies under different circumstances, and depends in a controlling degree on its judicious use. Sugar fed without any suitable admixture has no feeding value; it is worthless as the sole food of an animal. Properly supplemented — as, for instance, in the sweet corn — its nutritive value is very high. Bread has a high feeding value for man; a cat fed exclusively with bread dies, after some weeks, under the symptoms of starvation.

To compound the animal diet with reference to the *particular organization* of the *animal*, its *age* and its *functions*, is of no more importance than to select the fodder substances with reference to *its special wants*, as far as the *absolute* and *relative quantity* of the *three essential groups* of *food constituents* are concerned.

As no single plant or part of plant has been found to supply economically and efficiently to any considerable extent the wants of our various kinds of farm stock, it becomes a matter of first importance to learn how to supplement our leading farm crops, to meet the divers wants of each kind. To secure the highest feeding value of each article of fodder is most desirable in the interest of good economy. To try to attain that end by means of the products of home industry is a safe beginning. For this purpose it is desirable that we should learn to look upon a plant, or a part of a plant, not as a whole, but to pay more attention towards their composition. A little more acquaintance with the composition of our fodder crops, — as far as the relative and the absolute quantity of the three principal groups of essential constituents of an animal diet are concerned, — cannot fail to enable us to compound fodder rations for our stock on a more rational basis. A thorough information regarding the general character of the crops, and an approximately correct idea regarding the chemical composition of the particular fodder on hand, are points of first importance when planning a rational and thus economical system of feeding for any particular kind of farm stock. A better knowledge of what we feed enables us to give a *more judicious explanation* of the results of our feeding experiments; it teaches us best, also, how to supplement our own fodder resources to meet the special wants of our farm stock.

Careful investigations in stock-feeding have taught us lessons similar to those we have learned to appreciate in feeding plants, or in the cultivation and the production of farm crops. All our farm plants need nitrogen, phosphoric and sulphuric acids, potassa, soda, lime, magnesia and iron; yet not two species of plants have been found which need the same quantity of these substances during their entire period of life, nor at any stage of their growth. No one of the above-stated essential mineral constituents of plants can replace another one to any extent without altering the character of the plant, or even endangering its life. Potassa cannot take the place of lime, nor phosphoric acid that of sulphuric acid. When lime is needed, a shovelful of that substance is worth more than any quantity of the many times more expensive potassa; that particular mineral element which supplies an actual want of the soil is, for this reason, from a physiological standpoint considered the most important one for the production of the plant; for without it the remaining essential mineral constituents of plants, whatever their quantity may be, cannot make them grow.

In regard to the growth and the support of our farm livestock, similar relations have been noticed. Actual feeding experiments have shown that three groups of plant constituents (nitrogenous, non-nitrogenous, and mineral constituents) are required to sustain successfully animal life. No one or two of them, alone, can support it for any length of time. In case the food does not contain digestible non-nitrogenous substances, the fat and a part of the muscles of the animal on trial will be consumed in the support of respiration before its life terminates. In case nitrogenous constituents are excluded, the formation of new blood and flesh from the food consumed ceases, for the animal system is not capable of producing their principal constituents from anything else than the nitrogenous constituents of the plants.

Herbivorous animals receive these substances directly from the plants ; carniverous animals indirectly, by feeding on herbivorous animals. We feed at present our farm stock too frequently without a due consideration of the general natural law of nutrition ; to deal out our fodder crops only with mere reference to name, instead of making ourselves more familiar with their composition and their particular quality, deprives us even of the chance of drawing an intelligent conclusion from our present system of feeding.

The peculiar character of our home-raised fodder articles is apt to conceal their special deficiency for the various purposes they are used for in a general farm management. They all contain the three essential food constituents, yet in widely varying proportions, and they ought, therefore, to be supplemented in different directions, to secure their full economical value. To resort to more or less of the same fodder article to meet the special wants, may meet the case as far as an *efficient* support of the animal is concerned, yet it can only in exceptional cases be considered good economy.

To satisfy the craving of the stomach and to feed a nutritious food are both requirements of a healthy animal diet, which, each in their own way, may be complied with. The commercial fodder substances, as oil-cakes, meat refuse, brans and our steadily increasing supply of refuse material from breweries, starch works, glucose factories, etc., are admirably fitted to supplement our farm resources for stock-feeding ; they can serve in regard to animal growth and support in a similar way as the commercial fertilizer in the growth of farm crops, by supplementing our home resources. To feed an excess of fodder materials, as roots and potatoes, which contain a large proportion of non-nitrogenous substances, as starch, sugar, digestible cellular substance, etc., means direct waste ; for they are ejected by the animal, and do not materially benefit the manure heap. In case of an excessive consumption of nitrogenous constituents, a part of the expense is saved in an increased value of the manure, yet scarcely enough to recommend that practice beyond mere exceptional cases. The aim, therefore, of an economical stock-feeding must be to compound our various fodder materials in such a manner that the largest quantity of each of the three groups of fodder substances which the animal is capable to assimilate should be contained in its daily diet to meet the purpose for which it is kept. To compound the fodder ration of our farm stock with reference to the special wants of each class of them is an essential requirement for a satisfactory performance of their functions; to supply these wants in an economical way controls the financial success of the industry.

The problem is an intricate one; years of careful experimenting were required to accumulate observations sufficient in number and in quality to impart to the conclusion arrived at the claim of being worthy of a serious consideration. The first attempt to lay down rules for compounding the fodder rations of all kinds of farm stock on rational scientific principles was made by Dr. Grouven, Director of the Agricultural Experiment Station, at Salzmünden, Germany, 1858–1864. He began his work with a critical compilation of feeding experiments made by competent parties, some ninety in number, his own extensive experiments included. He ascertained, in each case, the amount of each fodder subtance consumed per day during each experiment; and calculated subsequently from their analyses the character and the amount of the daily fodder rations.

By this operation he learned the exact amount of nitrogenous, non-nitrogenous and mineral substances digested per day, under definite circumstances, by each class of farm animals. The amount of fat which had been fed in the fodder substances was separately recorded on account of its exceptionally high feeding value as a heat-producing material. The results of his calculations were repeatedly tried by actual feeding experiments, to test the correctness of his conclusions. The main object of Grouven's work consisted in bringing the results of more than twenty years' careful investigations within the reach of the practical farmer. In presenting his fodder standards to them, he recognized the natural imperfections of a first effort. More than twenty years' additional experience in leading European agricultural experiment stations has modified some details in

Grouven's statement; yet the great value of his method, to compound rational and thus more economical fodder rations for farm animals, has received an unqualified endorsement.

As the revised feeding standards deserve the most serious attention of all those who take an active part in studying the best and most economical mode of stock-feeding with reference to our leading fodder resources, I insert in this connection the latest edition for 1883 (Mentzel and Lengerke, Berlin). As a starting point for future feeding experiments, they furnish most valuable instructions.

(A.) *By Day, and 1,000 lbs. Live Weight.*

KIND OF ANIMAL.	Dry organic matter.	DIGESTIBLE MATTER IN THE FODDER.			Sum of Nutritive matter.	Nutritive ratio.
		Albuminoids.	Carbo-hydrates.	Fat.		
1. *Oxen,*—	lbs.	lbs.	lbs.	lbs.	lbs.	
At rest, ...	17.5	0.7	8.0	0.15	8.85	11 :2.0
2. *Sheep,*—						
Coarse breed, . .	20.0	1 2	10.3	0.20	11.70	1 :9.0
Fine breed, ...	22.5	1.5	11.4	0.25	13.15	1 :8.0
3. *Oxen,*—						
At medium work, . .	24 0	1.6	11.3	0.30	13.20	1 :7 5
At hard work, . .	26.0	2.4	13.2	0 50	16.10	1 :6.0
4. *Horse,*—						
At easy work,	21.0	1.5	9.5	0.40	11.40	1 :7.0
At medium work, . .	22 5	1.8	11.2	0.60	13.60	1 :7.0
At hard work, . .	25.5	2.8	13.4	0 80	17.00	1 :5.5
5. *Milch Cow,*—	24.0	2.5	12.5	0.40	15.40	1 :5.4
6. *Fattening Ox,*—						
1st period, ...	27.0	2.5	15.0	0.50	18.00	1 :6 5
2d "	26.0	3.0	14.8	0.70	18.50	1 :5.5
3d "	25.0	2.7	14.8	0.60	18.10	1 :6.0
7. *Fattening Sheep,*—						
1st period, ...	26.0	3.0	15.2	0.50	18.70	1 :5.5
2d "	25.0	3.5	14.4	0.60	18.50	1 :4.5
8. *Fattening Hog,*—						
1st period, ...	36.0	5.0	27.5		32.50	1 :5 5
2d "	31.0	4.0	24.0		28.00	1 :6.0
3d "	23 5	2.7	17.5		20.20	1 :6.5
9. *Growing Cattle,*—						
Months old. — Medium live weight per head.						
2–3, . . 150 lbs., .	22.0	4.0	13.8	2.0	19.8	1 :4.7
3–6, . . 300 lbs., .	23.4	3.2	13.5	1.0	17.7	1 :5.0
6–12, . . 500 lbs , .	24.0	2.5	13.5	0.6	16.6	1 :6.0
12–18, . . 700 lbs., .	24.0	2.0	13.0	0.4	15.4	1 :7.0
18–24, . . 850 lbs., .	24.0	1.6	12.0	0.3	13.9	1 :8.0

(A.) *By Day, and 1,000 lbs. Live Weight* — Continued.

Kind of Animal.		Dry organic matter.	Digestible Matter in the Fodder.			Sum of Nutritive matter.	Nutritive ratio.
			Albuminoids.	Carbo-hydrates.	Fat.		
10. *Growing Sheep,* —							
Months old.	Medium live weight per head.	lbs.	lbs.	lbs.	lbs.	lbs.	
5–6,	56 lbs.,	28.0	3.2	15.6	0.8	19.6	1 :5.5
6–8,	67 lbs.,	25.0	2.7	13.3	0.6	16.6	1 :5.5
8–11,	75 lbs.,	23.0	2.1	11.4	0.5	14.0	1 :6.0
11–15,	82 lbs.,	22.5	1.7	10.9	0.4	13.0	1 :7.0
15–20,	85 lbs.,	22.0	1.4	10.4	0.3	12.1	1 :8.0
11. *Growing Fattening Swine,* —							
2–3,	50 lbs.,	42.0	7.5	30.0		37.5	1 :4.0
3–5,	100 lbs.,	34.0	5.0	25.0		30.0	1 :5.0
5–6,	125 lbs.,	31.5	4.3	23.7		28.0	1 :5.5
6–8,	170 lbs.,	27.0	3.4	20.4		23.8	1 :6.0
8–12,	250 lbs.,	21.0	2.5	16.2		18.7	1 :6.5

(B.) *By Head and by Day.*

Kind of Animal.		Dry organic matter.	Digestible Matter in the Fodder.			Sum of Nutritive matter.	Nutritive ratio.
			Albuminoids.	Carbo-hydrates.	Fat.		
Growing Cattle,—							
Months old.	Medium live weight per head.	lbs.	lbs.	lbs.	lbs.	lbs.	
2–3,	150 lbs.,	3.3	0.6	2.1	0.30	3.00	1 :4.7
3–5,	300 lbs.,	7.0	1.0	4.1	0.30	5.40	1 :5.0
5–6,	500 lbs.,	12.0	1.3	6.8	0.30	8.40	1 :6.0
6–8,	700 lbs.,	16.8	1.4	9.1	0.28	10.78	1 :7.0
8–12,	800 lbs.,	20.4	1.4	10.3	0.26	11.96	1 :8.0
Growing Sheep,—							
5–6,	56 lbs.,	1.6	0.18	0.87	0.045	1.095	1 :5.5
6–8,	67 lbs.,	1.7	0.17	0.85	0.040	1.060	1 :5.5
8–11,	75 lbs.,	1.7	0.16	0.85	0.037	1.047	1 :6.0
11–15,	82 lbs.,	1.8	0.14	0.89	0.032	1.062	1 :7.0
15–20,	85 lbs.,	1.9	0.12	0.88	0.025	1.047	1 :8.0
Growing Fattening Swine,—							
2–3,	50 lbs.,	2.1	0.38	1.50		1.88	1 :4.0
3–5,	100 lbs.,	3.4	0.50	2.50		3.00	15.0
5–6,	125 lbs.,	3.9	0.54	2.96		3.50	1 :5.5
6–8,	170 lbs.,	4.6	0.58	3.47		4.05	1 :6.0
8–12,	250 lbs.,	5.2	0.62	4.05		4.67	1 :6.5